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- Lee, Jin-ho, c/o 708-201 Seokwang Apartment Suwon-si, Gyeonggi-do (KR)
- Cho, Jon-woo, c/o 1006-303, Samsung Apartment Seongnam-si, Gyeonggi-do (KR)

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(74) Representative: **Ertl, Nicholas Justin  
Elkington and Fife LLP,  
Prospect House,  
8 Pembroke Road  
Sevenoaks, Kent TN13 1XR (GB)**

(71) Applicant: **Samsung Electronics Co., Ltd.  
Suwon-si, Gyeonggi-do (KR)**

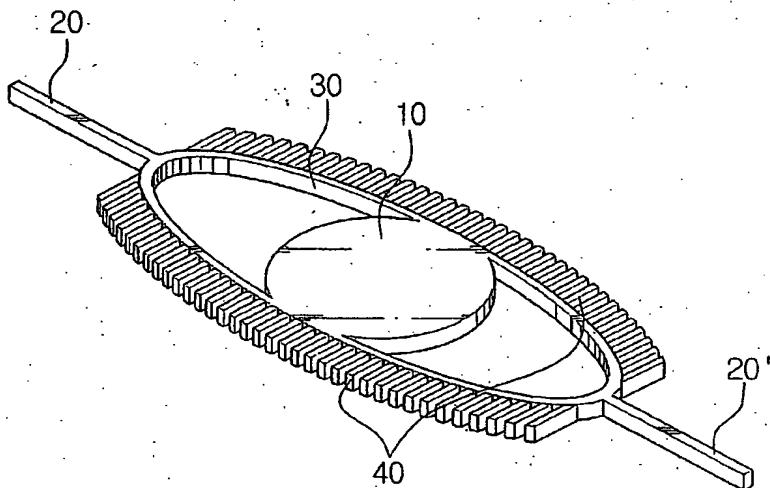
(72) Inventors:  
• Ko, Young-chul, c/o 173-501, Kolong Apartment Suwon-si, Gyeonggi-do (KR)

### (54) Micro mirror

(57) A micro mirror structure having an increased driving angle while being driven in high speed. The micro mirror includes a rotatable mirror section that reflects light, a pair of spring sections for supporting the mirror section and serving as a rotational axis for the mirror section when the mirror section is rotationally driven, an oval adjoining section for connecting the mirror section and the pair of spring sections, and a driving section in-

cluding mobile combs arranged on the adjoining section. A fixed comb is provided above and/or below the mobile combs to correspond to the mobile combs to generate electrostatic force. According to the present invention, by existence of the oval adjoining section, moment can be increased without largely increasing rotational inertia moment. Therefore, a high-speed optical scanner with an increased driving angle can be provided, which is required for a high-resolution laser TV.

FIG. 3



## Description

**[0001]** Apparatuses and methods consistent with the present invention relate to a micro mirror, and in particular, to a micro mirror capable of being used as an optical scanner for scanning laser beams in a display device such as a laser TV, and a method for fabricating the same.

**[0002]** As the age of multimedia has arrived, the demand for large displays has increased and various types of large-display devices are being successively introduced. A laser TV is proposed as a display device for the next generation that can implement high-resolution at a low price and provide a large size.

**[0003]** Such a laser TV includes an optical scanner that scans laser beams projected from a laser diode module in horizontal and vertical directions according to RGB image signals. The optical scanner includes a micro mirror fabricated on the basis of Micro-Electro Mechanical System (MEMS).

**[0004]** FIGS. 1A and 1B schematically illustrate different types of micro mirrors publicly known in the prior art, and FIG. 2 is a drawing for describing the operations of these micro mirrors.

**[0005]** As can be seen from the drawings, a micro mirror comprises a rotatable mirror section 1, a pair of spring sections 2 and 2' connected to the mirror section 1 to support the mirror section 1 and to serve as a rotation axis when the mirror section 1 rotates, a mobile comb 3, and a fixed comb 4.

**[0006]** The mobile comb 3 and the fixed comb 4 have a plurality of comb-fingers 3a, 3b, ...; 4a, 4b, ..., respectively. The mobile comb 3 may be installed either on the mirror section 1 as shown in FIG. 1 A or on the spring sections 2 and 2' as shown in FIG. 1B. The fixed comb 4 may be installed above or below the mobile comb 3, as shown in FIG. 2, wherein they are arranged in such a manner that the comb-fingers 3a, 3b, ... of the mobile comb 3 and the comb-fingers 4a, 4b, ... of the fixed comb 4 clasp each other.

**[0007]** Therefore, if plus (+) voltage is applied to one side comb-fingers 4a among the comb-fingers 4a, 4b of the fixed comb 4 corresponding to the comb-fingers 3a, 3b of the mobile comb 3 electrified to minus (-), electrostatic force is generated between the comb-fingers 3a and 4a, and accordingly, the mirror section 1 is rotationally driven about the spring sections 2 and 2', as indicated by dotted lines in FIG. 2. Whereas, if plus (+) voltage is applied to the other side comb-fingers 4b, the mirror section 1 is rotationally driven in the reverse direction. Due to this rotational driving of the mirror section 1, incident light is scanned to a scanning surface while being continuously and uniformly reflected to a predetermined angle range.

**[0008]** The driving velocity of the micro mirror is related to resolution of a display device, and the driving angle is related to a picture screen size of such a display device. That is, as the driving velocity of the micro mirror

is increased, the resolution is also increased, and as the driving angle is increased, the picture screen is also increased. Therefore, in order to implement a large high-resolution laser TV, an optical scanner such as a micro mirror is required which has an increased driving angle while being driven at high velocity.

**[0009]** However, since driving velocity and driving angle of a micro mirror conflict with each other, there is difficulty in increasing driving angle of a micro mirror and the driving velocity thereof at the same time. Resonance driving may be used in order to increase a driving angle of a micro mirror. However, this has a problem in that the yield of production is very low since it is very difficult to match the natural frequency of a micro mirror with a driving frequency due to errors in fabrication, and thus a tuning structure is required for tuning the driving frequency.

**[0010]** In a conventional micro mirror as shown in FIG. 1A, the mobile comb 3 is arranged on the opposite sides of a mirror section 1, in which case since a distance D<sub>1</sub> from the rotational center of the mirror section 1 is long, a moment is increased as compared to the case in which the comb fingers of the mobile combs 3 are arranged on the spring sections 2 and 2' as shown in FIG. 1 B, if the same number of comb-fingers are employed. However, in this case, the number of mobile combs 3 is limited, and in addition, the size of mirror section 1 is increased in order to provide an increased number of comb-fingers of a mobile comb 3, and thus the inertia moment will be increased, and the natural frequency of the mirror will be lowered. Accordingly, driving velocity can not be increased.

**[0011]** Meanwhile, in a micro mirror as shown in FIG. 1 B, the mobile combs 3 are arranged on spring sections 2 and 2', in which case it is possible to reduce the magnitude of rotational inertia moment while increasing the number of mobile combs 3, as compared to the mirror having the structure shown in FIG. 1A. However, it is impossible to obtain a sufficient driving angle since the distance D<sub>2</sub> from the central axis of the mirror section is short, thereby generating low moment. In addition, this case has a problem in that the rigidity of the spring sections 2 and 2' is not uniform due to a process error or the like.

**[0012]** Thus, in the conventional micro mirrors as described above it is hard to provide a high driving velocity and an increased driving angle due to their constructions. Therefore, the conventional micro mirrors are not suitable for an optical scanner for a large high-resolution laser TV.

**[0013]** According to a non-limiting, illustrative embodiment of the present invention, there is provided a micro mirror comprising a rotatable mirror section that reflects light, a pair of spring sections for supporting the mirror section and serving as a rotational axis for the mirror section when the mirror section is rotated, an adjoining section for connecting the mirror section and the pair of spring sections. A driving section is provided comprising

a mobile comb mounted in the adjoining section and a fixed comb disposed corresponding to the mobile comb to generate electrostatic force.

**[0014]** The mirror section may be formed in a circular shape for reflecting light with a minimum area, however, the shape is not limited so.

**[0015]** The adjoining section may be formed in an oval shape because more mobile combs can be provided thereon and the oval shape is advantageous in view of rotational inertia moment. However, the shape is not limited so.

**[0016]** According to an embodiment of the present invention, the micro mirror is positioned in such a manner that its minor axis portion is circumscribed to the circumference of the circular mirror section.

**[0017]** The pair of spring sections perform torsional motion when the mirror section is rotated. The mobile comb and the fixed comb of the driving section are provided with a plurality of comb-fingers, respectively, and these fingers are correspondingly arranged to clasp one another. It is also contemplated that the fingers of the mobile comb may be arranged on the outer periphery of the adjoining section, or on both of the inner and outer peripheries of the adjoining section. Further, the fingers of the mobile comb may be arranged on the inner and/or outer periphery and on both sides of the pair of spring sections.

**[0018]** In addition, the fixed comb may be arranged both above and below the mobile comb. If the fixed comb is arranged both above and below the mobile comb, the driving angle of the mirror section can be further increased because more increased electrostatic force can be applied between the one mobile comb and fixed comb.

**[0019]** According to another aspect of the present invention, there is provided a micro mirror comprising a rotatable mirror section that reflects light; a pair of spring sections for supporting the mirror section and serving as a rotational axis for the mirror section when the mirror section is rotationally driven; a first adjoining section for connecting the mirror section and the pair of spring sections. It is contemplated that the first adjoining section is arranged to be circumscribed to the circumference of the mirror section in one diametrical direction and connected to the pair of spring sections in another diametrical direction. A second adjoining section is connected to a connection portion between the pair of spring sections of the first adjoining section with one end, and connected to the mirror section at the portion opposed to the connection portion with the other end. A driving section is provided that comprises a mobile comb arranged on the first adjoining section, and a fixed comb provided above or below the mobile combs to correspond to the mobile combs to generate electrostatic force.

**[0020]** It is preferable but not limited to or necessary to form the mirror section in a circular shape, the first adjoining section in an oval shape, and each second adjoining section in a straight-line shape.

**[0021]** The fingers of the mobile comb may be arranged on the periphery of the first adjoining section, on both of the inner and outer peripheries of the first adjoining section, or on the opposite sides of the pair of the second adjoining sections. In addition, fingers of the fixed comb may be additionally arranged on the opposite sides of the pair of the spring sections. Further, the fixed comb may be arranged both above and below the mobile comb.

**[0022]** In order to achieve the afore-mentioned aspect of the present invention, there is also provided a method for fabricating a micro mirror comprising steps of forming a first metal electrode on a first glass, b) forming a first fixed comb on a first wafer through a predetermined process, c) bonding the first glass and the first wafer, and polishing the first wafer to a mirror thickness, d) forming a mirror section, a spring section, an adjoining section and a mobile comb in the first wafer polished to the mirror thickness, through a predetermined process, e) bonding a second glass patterned to form a second metal electrode and a second wafer patterned to form a second fixed comb, and polishing the second wafer to a comb thickness after bonding the second glass and the second wafer, f) forming the second metal electrode on the second glass through the patterning of the second glass, g) forming the second fixed comb on the second wafer polished to a comb thickness through a predetermined process, and h) assembling a subassembly of step d) and a subassembly of step g) by bonding, and 30 then bonding first and second wires for applying driving voltage to the first and second metal electrodes.

**[0023]** Step a) comprises steps of providing a Pyrex glass having a predetermined thickness, forming a line hole for the first metal electrode on the glass by etching, 35 coating a metal layer to a predetermined thickness on the surface of the glass having the line hole, and removing the metal layer by etching except the metal layer above the line hole.

**[0024]** Step b) comprises steps of providing a highly 40 doped SOI wafer having a silicone layer of a predetermined thickness, a single crystal silicon layer and a SiO<sub>2</sub> layer interposed between the silicon layers, and forming a plurality of comb-fingers of the first fixed comb in the single crystal silicon layer through a photolithography process.

**[0025]** In addition, step d) comprises step of forming an Au reflection part for reflecting light on the surface of the mirror section, wherein the mirror section, spring sections, adjoining section, and mobile sections are 50 formed by a photolithography process.

**[0026]** The present invention thus provides an improved micro mirror to increase moment while reducing rotational inertia moment so that the micro mirror can be used as a high-speed optical scanner having an increased driving angle, and a method for fabricating the same.

**[0027]** The above and other aspects, features and advantages of the present invention will be more apparent

from the following detailed description taken with reference to the accompanying drawings, in which:

**FIGS. 1A and 1B** are top plan views schematically showing the structure of a conventional micro mirror;

**FIG. 2** is a view for illustrating the operation of the micro mirrors shown in **FIG. 1**;

**FIG. 3** is a perspective view schematically showing the structure of a micro mirror according to a first non-limiting, illustrative embodiment of the present invention;

**FIGS. 4A and 4B** are schematic views for illustrating the operation of the micro mirror according to the first embodiment as shown in **FIG. 3**, in which **FIG. 4A** shows an application of a fixed comb provided below a mobile comb, and **FIG. 4B** shows an application of two fixed combs provided above and below a mobile comb;

**FIG. 5** is a perspective view schematically showing a construction of a micro mirror according to a second exemplary embodiment of the present invention;

**FIG. 6** is a perspective view schematically showing a construction of a micro mirror according to a third exemplary embodiment of the present invention;

**FIG. 7** is a perspective view schematically showing a construction of a micro mirror according to a fourth exemplary embodiment of the present invention;

**FIG. 8** is a perspective view schematically showing a construction of a micro mirror according to a fifth exemplary embodiment of the present invention;

**FIG. 9** is a perspective view schematically showing a construction of a micro mirror according to a sixth exemplary embodiment of the present invention;

**FIG. 10** is a perspective view schematically showing a construction of a micro mirror according to a seventh exemplary embodiment of the present invention;

**FIG. 11** is a perspective view schematically showing a construction of a micro mirror according to an eighth exemplary embodiment of the present invention;

**FIGS. 12A to 12F** illustrate a process of fabricating a lower structure of a micro mirror according to the present invention;

**FIGS. 13A to 13F** illustrate a process of fabricating an upper structure of a micro mirror according to the present invention; and

**FIG. 14** shows the lower structure and the upper structure fabricated according to the processes as shown in **FIGS. 12A-F** and **13A-F**, respectively, in an assembled state.

**[0028]** As shown in **FIGS. 3, 4A and 4B**, a mirror section 10 for reflecting light in a micro mirror according to a first embodiment of the present invention is formed in a circular shape having a minimum area for reflecting

light. Although the mirror section 10 is not limited to a circular shape, the circular shape does not increase rotational inertia moment so largely. The radius of the mirror section 10 can be properly adjusted depending on a radius of light to be used.

**[0029]** Such a mirror is rotationally driven within a predetermined angular range about a pair of spring sections 20 and 20'. The pair of springs 20 and 20' support the mirror section and perform torsion motion when the mirror section 10 is rotationally driven.

**[0030]** An adjoining section 30 connects the mirror section 10 and the pair of spring sections 20 and 20'. The adjoining section 30 is formed in an oval shape, and the mirror section 10 is positioned within the adjoining section 30. The minor axis portions on the inner periphery of the oval adjoining section 30 and the corresponding parts on the outer periphery of the mirror section 10 are connected with each other. The major axis portions of the adjoining section 30 are connected to the pair of spring sections 20 and 20', respectively. With this arrangement of the mirror section 10 and the adjoining section 30, predetermined spaces are provided within the oval adjoining section 30, that is, between the inner periphery portion of the adjoining section 30 extended from the minor axis to the major axis thereof and the non-circumscribed outer periphery portion of the mirror section 10.

**[0031]** The shape of the adjoining section 30 is not limited to an oval shape. However, the oval shape allows more comb-fingers to be installed on the adjoining section 30 and does not increase rotational inertia moment so largely so that the driving angle of the micro mirror can be maximized.

**[0032]** A mobile comb 40 comprises a plurality of comb-fingers 40a, 40b, and the comb-fingers 40a, 40b are equi-spaced around the circumference of the oval adjoining section 30. Compared to a conventional structure, in the present embodiment, the area of the mirror section or the like affecting rotational inertia moment is rather reduced while allowing more comb-fingers to be arranged on the mobile comb 40 as compared to a conventional one.

**[0033]** A fixed comb 50 is also provided that has a plurality of comb-fingers 50a, 50b, respectively, in which the comb-fingers 50a, 50b are arranged below the mobile comb 40 as can be seen from **FIG. 4A**. At this time, the comb fingers 40a, 40b of the mobile comb 40 and the comb fingers 50a, 50b of the fixed comb 50 are arranged to clasp one another. Alternatively, the fixed comb 50 may be disposed above the mobile comb 40.

**[0034]** As shown in **FIG. 4B**, it is possible to provide an embodiment in which a first fixed comb 50 is arranged below the mobile comb 40, and a second fixed comb 50' is arranged above the mobile comb 40.

**[0035]** In the mirrors as described above, electrostatic force is applied to the mobile comb 40 arranged on the adjoining section by the fixed comb 50 installed to be engaged with the mobile comb 40, as shown in **FIG. 4A**.

The electrostatic force induces rotational force, in which the spring sections 20 and 20' of the mirror section 10 serve as a center axis for the rotational force. Accordingly, the mirror section 10 rotates about the spring sections 20 and 20', and if the voltage of the fixed comb 50 is applied in a constant driving frequency, the mirror section 10 will be repeatedly rotated with the driving frequency.

**[0036]** The micro mirror as shown in FIG. 4B has first and second fixed combs 50, 50' arranged above and below the mobile comb 40, respectively. In this case, since the electrostatic force between the mobile comb 40 and the fixed combs 50, 50' is doubled as compared to the case shown in FIG. 4A, a more increased driving angle of the mirror can be obtained. In addition, since the electrostatic force is equally applied to the mirror section 10 in up and down directions, the mirror section can be smoothly driven without being vibrated up and down.

**[0037]** As described above, a micro mirror construction proposed by the present invention has an increased driving angle and high natural frequency as compared to the conventional micro mirror. Therefore, the inventive micro mirror can accomplish an increased driving angle while being driven in high velocity, the principle of which will be described using a following equation.

**[0038]** If any attenuation component is disregarded, motion of a rotating body may be expressed by the following equation:

$$J\ddot{\theta} + k\theta = M$$

wherein J is a rotational inertia moment, k is a torsional spring constant, and M is an applied torque.

**[0039]** The natural frequency for the rotational motion of this system is expressed as follows:

$$f = \frac{1}{2\pi\sqrt{\frac{k}{J}}}$$

**[0040]** According to the above equations, with micro mirrors designed to have the same natural frequency, if the rotational inertia moment J is reduced, the torsional spring constant k can be reduced, and therefore, the driving angle can be increased even with small force.

**[0041]** As a result of analyzing a conventional construction and an inventive construction using an ANSYS program for computer simulation, when the two constructions are driven with the same driving frequency (33.75 KHz) after designing the constructions each to have a natural frequency of 40 KHz, the driving angle of the conventional one is 2.3 degrees while that of the inventive one is 4.0 degrees.

**[0042]** FIG. 5 shows a micro mirror according to a second embodiment of the present invention.

**[0043]** As shown in the drawing, the basic construc-

tion and operation of the micro mirror according to the second embodiment is the same as that of the first embodiment described above. Therefore, the similar parts are indicated by similar reference numerals. However, detailed description thereof is omitted, and only the characteristic construction of this embodiment is described. Other various embodiments will be shown and described later in this manner.

**[0044]** As shown in FIG. 5, in the present embodiment, the mobile combs 140 are arranged on the inner periphery as well as on the outer periphery of the oval adjoining section 130. The adjoining section 130 connects the mirror section 110 and the pair of spring sections 120 and 120'. Although not specifically shown, the fixed combs are provided above and/or below the mobile combs 140 to correspond to the mobile combs 140. In addition, the fixed combs may be arranged above and/or below the mobile combs 140.

**[0045]** In a micro mirror according to a third embodiment of the present invention as shown in FIG. 6, mobile combs 240 are provided on the outer periphery of an oval adjoining section 230 and on opposite sides of spring sections 220 and 220'. The adjoining section 230 connects the mirror section 210 and the pair of spring sections 220 and 220'. In addition, although not shown in the drawing, mobile combs may be additionally provided on the inner periphery of the adjoining section 230. As would be appreciated by one skilled in the art, fixed combs may be installed above and/or below the respective mobile combs in this and later embodiments, in a manner similar to that described in regard to Figs. 4A and 4B.

**[0046]** FIG. 7 shows a micro mirror according to a fourth embodiment of the present invention. As shown in FIG. 7, the fourth embodiment of the present invention comprises a circular mirror section 310, a pair of spring sections 320 and 320', a first adjoining section 330 of an oval shape, a pair of second adjoining sections 330a and 330b having a straight line shape extended from the portions where the spring sections 320 and 320' are adjoined to the first adjoining section 330, to the mirror section 310. The mobile combs 340 and fixed combs construct a driving section. The mobile combs 340 are arranged on the outer periphery of the first adjoining section 330 and on the opposite sides of each second adjoining section 330a and 330b.

**[0047]** In addition, a micro mirror according to a fifth embodiment of the present invention, as shown in FIG. 8, has a mirror section 410, a pair of spring sections 420 and 420', and a pair of second adjoining sections 430a and 430b. Mobile combs 440 are arranged on the inner and outer peripheries of the first adjoining section 430 unlike the fourth embodiment.

**[0048]** FIGS. 9 to 11 respectively show sixth to eighth embodiments. The sixth embodiment of FIG. 9 is a micro mirror provided with mobile combs 540 on the periphery of a first adjoining section 530 and on the opposite sides of a pair of spring sections 520 and 520' thereof, respec-

tively. A mirror section 510 is provided along with a pair of second adjoining sections 530a and 530b. The seventh embodiment of FIG. 10 is a micro mirror provided with a mirror section 610. Mobile combs 640 are disposed on the outer periphery of a first adjoining section 630, on the opposite sides of a pair of spring sections 620 and 620' and on the opposite sides of each second adjoining section 630a and 630b, respectively. Additionally, the eighth embodiment of FIG. 11 is a micro mirror provided with mobile combs 740 on the inner and outer peripheries of a first adjoining section 730 and on the opposite sides of a pair of springs 720 and 720', respectively. A mirror section 710 is also provided along with a pair of second adjoining sections 730a and 730b.

**[0049]** As can be seen from the constructions of the various embodiments above, the inventive mirrors commonly have an oval adjoining section which does not increase rotational inertia moment so largely while the area of a circular mirror section can be minimized and more mobile combs can be provided on the adjoining section. Accordingly, it is possible to implement an increased driving angle while increasing driving velocity of a micro mirror.

**[0050]** Hereinbelow, a method of fabricating the inventive micro mirror will be described with reference to FIGS. 12 to 14. In this embodiment, a method of fabricating a micro mirror in which first and second fixed combs are arranged above and below a mobile comb is described.

**[0051]** FIGS. 12A to 12F show steps of fabricating a lower structure of a micro mirror.

**[0052]** First, first metal electrodes 811 and 812 are formed on a first glass 810 having a predetermined thickness, as shown in FIG. 12A. A Pyrex glass may be used for the glass 810. The metal electrodes 811 and 812 may be formed through steps of etching electrode-forming areas on the first glass 810 to form line holes for the metal electrodes 811 and 812, coating an electrode metal layer on the entire surface of the glass 810 to a predetermined thickness, and wet-etching the electrode metal layer to leave the metal layer only on the line holes.

**[0053]** After preparing the first glass 810 having metal electrodes 811 and 812 as described above, a first wafer 820 is provided as shown in FIG. 12B. The first wafer 820 is a highly doped SOI wafer having a silicon layer 821 of a predetermined thickness, a single crystal silicon layer 822 and a SiO<sub>2</sub> layer 823 interposed between the silicon layer 821 and the SiO<sub>2</sub> layer 823.

**[0054]** The single crystal silicon layer 822 of the first wafer 820 is formed with a plurality of comb-fingers 824 which form a first fixed comb. The plurality of comb-fingers 824 may be formed by a photolithography process, for example.

**[0055]** FIG. 12D shows a state in which the silicon layer 821 of the first wafer 820 is polished to a certain thickness for forming a mirror after the first glass 810 and the first wafer 820 are bonded to each other. The certain

thickness may be set within a range approximately of 50μm ~ 200μm.

**[0056]** On the surface of the polished silicon layer 821 of the first wafer 820, bonding areas 825 and 825', and a reflection area 826 are formed at proper positions. Both of the bonding areas 825 and 825' and the reflection area 826 are formed from Au, by depositing Au on the silicon layer 821 to a predetermined thickness and then etching the Au layer to remove a useless area.

**[0057]** As can be seen from FIG. 12F, a mirror section 827, spring sections 828, mobile comb 829, and an adjoining section (not shown) are formed in the silicon layer 821 through a photolithography process, for example.

**[0058]** FIGS. 13A to 13F illustrate steps of fabricating an upper structure of a micro mirror.

**[0059]** FIG. 13A and FIG. 13B show a second wafer 830 and a second glass 840, respectively. The second wafer 830 is a highly doped silicon wafer, and the second glass 840 has a DFR film 841. The second wafer 830 has a pattern section 831 for forming a second fixed comb, and the second glass 840 also has a pattern section 842 patterned to form second metal electrodes 843 and 844.

**[0060]** The second wafer 830 and the second glass 840 are bonded to each other as shown in FIG. 13C, and then predetermined second electrodes 843 and 844 are formed through the pattern section 842 of the second glass 840, as shown in FIG. 13D. The second metal electrodes 843 and 844 are formed by patterning the electrodes using a mask after coating a metal layer.

**[0061]** FIG. 13E shows bonding parts 832 and 832' formed on predetermined positions on the second wafer 830. The bonding parts 832 and 832' are formed by depositing Au on the surface of the second wafer, plating AuSn and then removing useless deposited layer and plated layer. Then, a plurality of comb-fingers 833 forming a second fixed comb are formed on the second wafer 830 as shown in FIG. 13F through a photolithography process, for example.

**[0062]** The lower structure and the upper structure each fabricated through the processes as described above are assembled by using bonding parts 825, 825', 832 and 832' formed on the respective structures, as shown in FIG. 14.

**[0063]** Finally, first and second wires (not shown) are bonded to apply driving voltage to the first and second metal electrodes 811 and 812, 843, 844 of the first and second glasses 810 and 840 in the structure assembled as described above.

**[0064]** As described above, according to the present invention, a micro mirror is implemented, which is capable of increasing moment without increasing rotational inertia moment so largely. Accordingly, a high-speed optical scanner with an increased driving angle can be provided such that it will be possible to accelerate development of next generation display devices such as a laser TV and marketing of products thereof.

**[0065]** While the embodiments of the present inven-

tion have been shown and described with reference to the embodiments thereof in order to exemplify the principle of the present invention, the present invention is not limited to the embodiments. It will be understood that various modifications and changes can be made by those skilled in the art without departing from the scope of the invention as defined by the appended claims. Therefore, it shall be considered that such modifications and changes thereof are all included within the scope of the present invention.

## Claims

### 1. A micro mirror comprising:

a rotatable mirror section that reflects light; a pair of spring sections which support the mirror section and serve as a rotational axis for the mirror section when the mirror section is rotationally driven; an adjoining section which connects the mirror section and the pair of spring sections; and a driving section comprising a mobile comb, and a fixed comb which generates electrostatic force, wherein the fixed comb is positioned above or below the mobile comb to correspond to the mobile comb.

### 2. The micro mirror according to claim 1, wherein the mirror section has a circular shape.

### 3. The micro mirror according to claim 1 or 2, wherein the adjoining section has an oval shape.

### 4. The micro mirror according to claim 1, wherein the mirror section has a circular shape and the adjoining section has an oval shape, and wherein the adjoining section is positioned in such a manner that its minor axis portions are circumscribed by the circumference of the mirror section.

### 5. The micro mirror according to any preceding claim, wherein the pair of spring sections perform torsional motion when the mirror section is rotationally driven.

### 6. The micro mirror according to any preceding claim, wherein fingers of the mobile comb are arranged on the outer periphery of the adjoining section.

### 7. The micro mirror according to any one of claims 1 to 5, wherein fingers of the mobile comb are arranged on both of inner and outer peripheries of the adjoining section.

### 8. The micro mirror according to any preceding claim, wherein the fixed comb is arranged above the mo-

bile comb and another fixed comb is arranged below the mobile comb.

9. The micro mirror according to claim 1, wherein the driving section comprises mobile combs arranged on the adjoining section and on the pair of spring sections, respectively, and fixed combs provided at least one of above and below the mobile combs to correspond to the mobile combs to generate electrostatic force.

### 10. The micro mirror according to claim 1, wherein:

the adjoining section is a first adjoining section arranged to be circumscribed by the circumference of the mirror section in one diametrical direction and connected to the pair of spring sections in another diametrical direction; the micro mirror further comprises second adjoining sections respectively connected to a connection portion between the pair of spring sections and the first adjoining section at one end, and connected to the mirror section at a portion opposed to the connection portion at another end; and the mobile comb of the driving section is arranged on the first adjoining section.

11. The micro mirror according to claim 10, wherein the mirror section has a circular shape, the first adjoining section has an oval shape, and the second adjoining sections have a straight-line shape.

12. The micro mirror according to claim 10 or 11, wherein the mobile comb has fingers which are arranged on an outer periphery of the first adjoining section.

13. The micro mirror according to claim 10 or 11, wherein the mobile comb has fingers which are arranged on both inner and outer peripheries of the first adjoining section.

14. The micro mirror according to claim 10 or 11, wherein the mobile comb has fingers which are arranged on a periphery of the first adjoining section and on opposite sides of the second adjoining sections.

15. The micro mirror according to any one of claims 10 to 14, wherein the fixed comb is arranged above the mobile comb and another fixed comb is arranged below the mobile comb.

16. The micro mirror according to any one of claims 10 to 15, wherein the mobile comb of the driving section is arranged respectively on the first and the second adjoining sections.

17. The micro mirror according to any one of claims 10

to 15, wherein the mobile comb of the driving section is arranged respectively on the first adjoining section and the pair of spring sections

18. The micro mirror according to any one of claims 10 to 15, wherein the mobile comb of the driving section is arranged respectively on the first adjoining section, the second adjoining sections and the pair of spring sections.

19. A method for fabricating a micro mirror comprising steps of:

- forming a first metal electrode on a first glass;
- forming a first fixed comb on a first wafer through a predetermined process;
- bonding the first glass and the first wafer and polishing the first wafer to a mirror thickness;
- forming a mirror section, a spring section, an adjoining section and a mobile comb in the first wafer polished to the mirror thickness, through a predetermined process;
- bonding a second glass patterned to form a second metal electrode and a second wafer patterned to form a second fixed comb, and polishing the second wafer to a thickness of the fixed comb;
- forming the second metal electrode on the second glass through the patterning of the second glass;
- forming the second fixed comb on the second wafer polished to the fixed comb thickness through a predetermined process; and
- assembling a subassembly of step d. and a subassembly of step g. by bonding, and then connecting first and second wires for applying driving voltage to the first and second metal electrodes.

20. The method according to claim 19, wherein step a. comprises steps of:

providing a Pyrex glass of a predetermined thickness;

forming a line hole for the first metal electrode on the glass by etching;

coating a metal layer to a predetermined thickness on the surface of the glass having the line hole; and

removing the metal layer by etching except the metal layer above the line hole.

21. The method according to claim 19 or 20, wherein step b. comprises :

providing a highly doped silicon on insulator wafer having a silicone layer of a predetermined thickness, a single crystal silicon layer

and a SiO<sub>2</sub> layer interposed between the silicon layers; and

forming a plurality of comb-fingers of the first fixed comb in the single crystal silicon layer through a photolithography process.

22. The method according to any one of claims 19 to 21, wherein step d. comprises a step of forming a reflection part for reflecting light from Au on the surface of the mirror section, wherein the mirror section, spring sections, adjoining section, and mobile section are formed by a photolithography process.

FIG. 1A

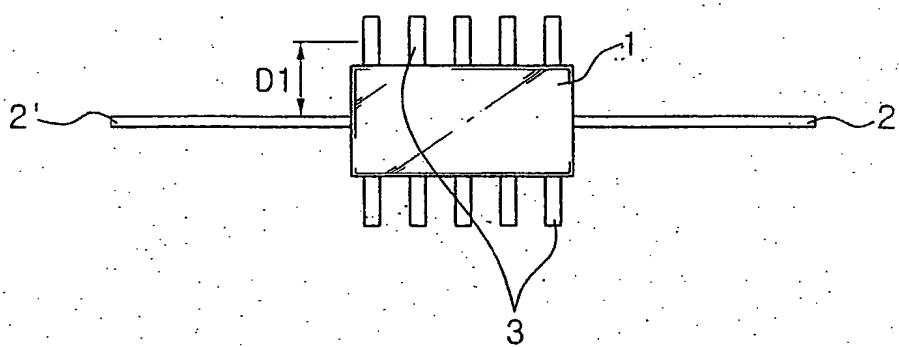


FIG. 1B

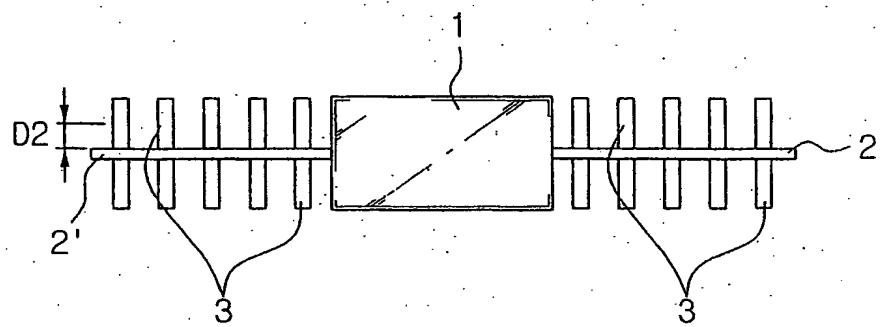


FIG. 2

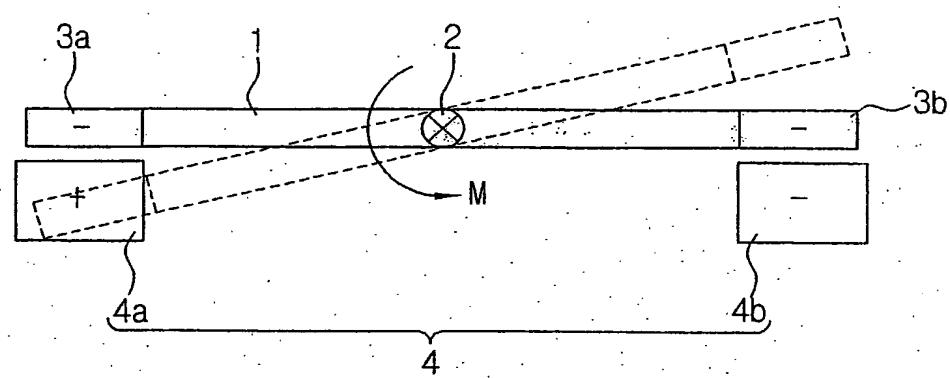


FIG. 3

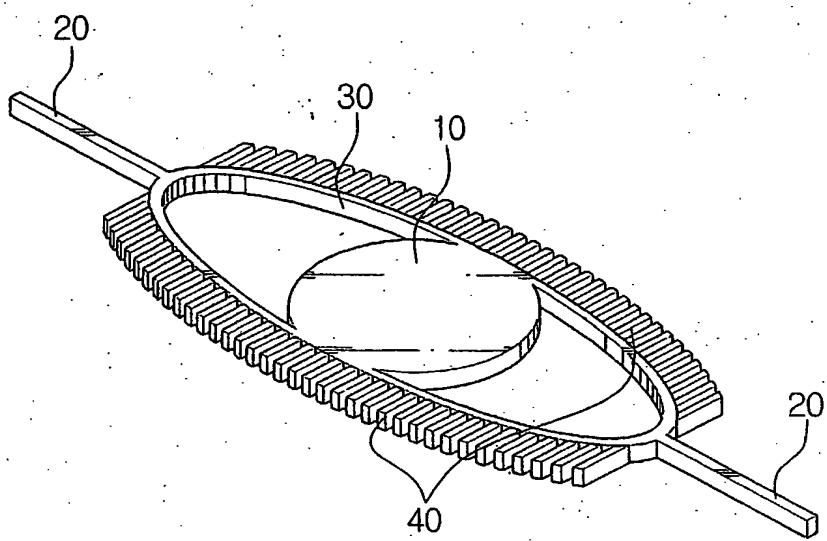


FIG. 4A

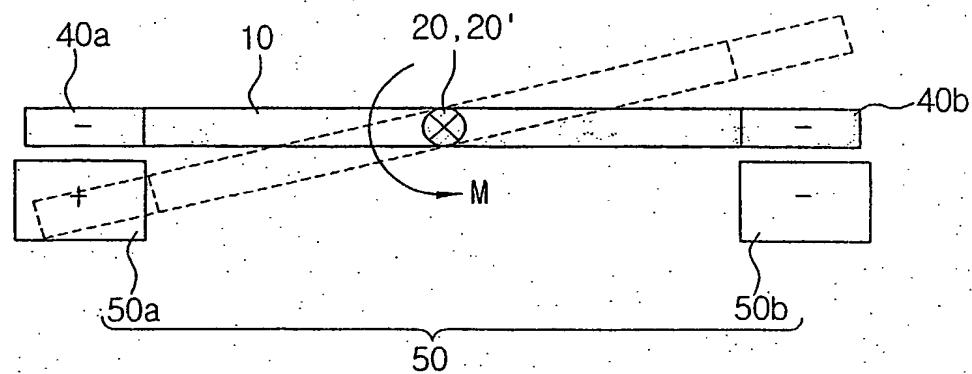


FIG. 4B

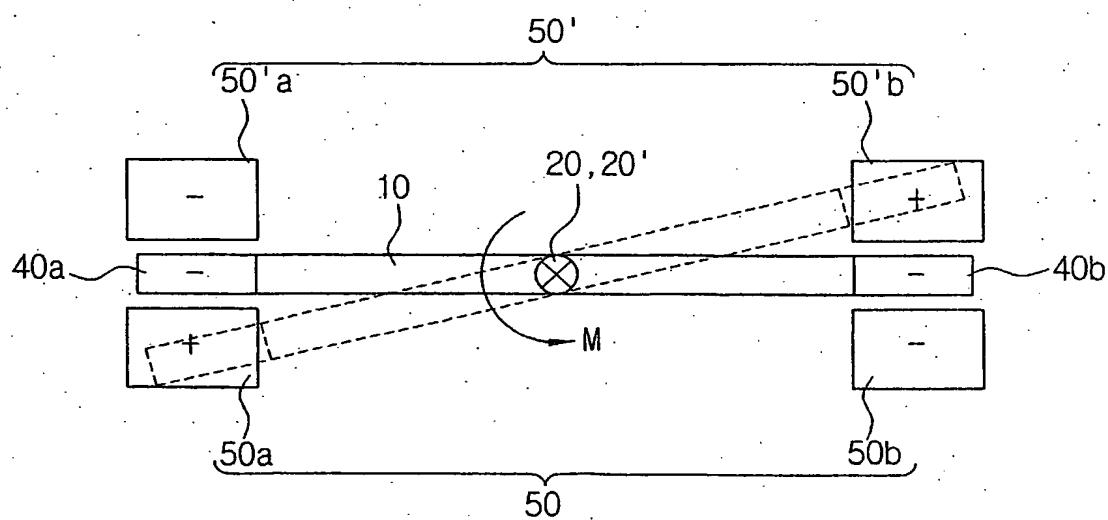


FIG. 5

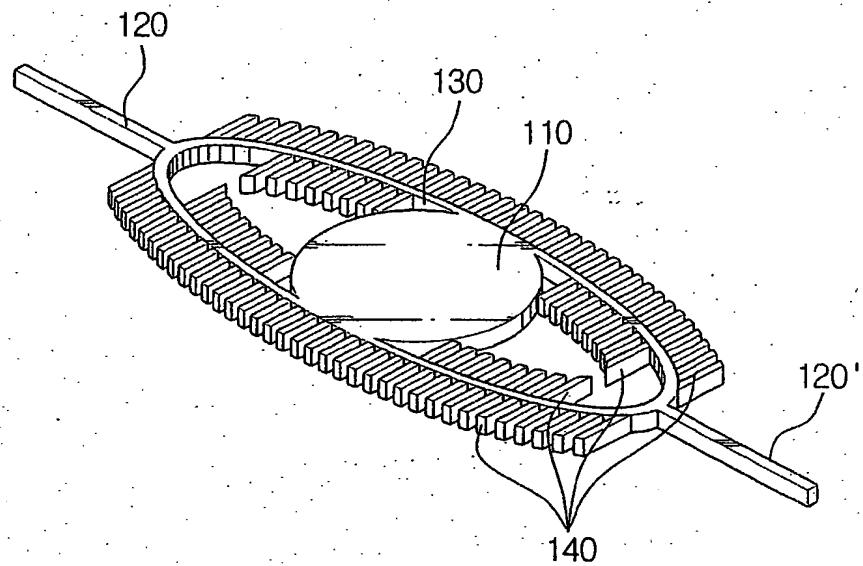


FIG. 6

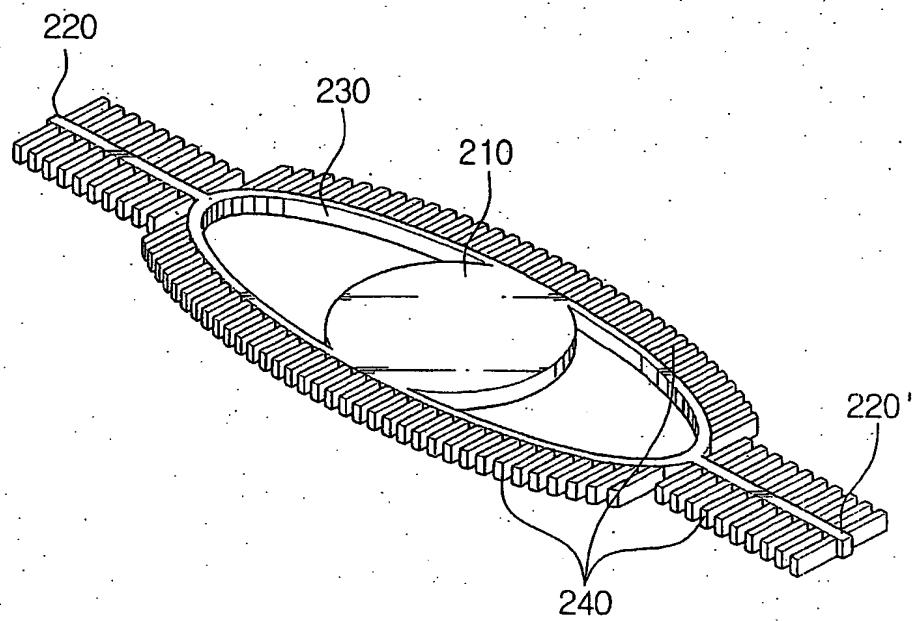


FIG. 7

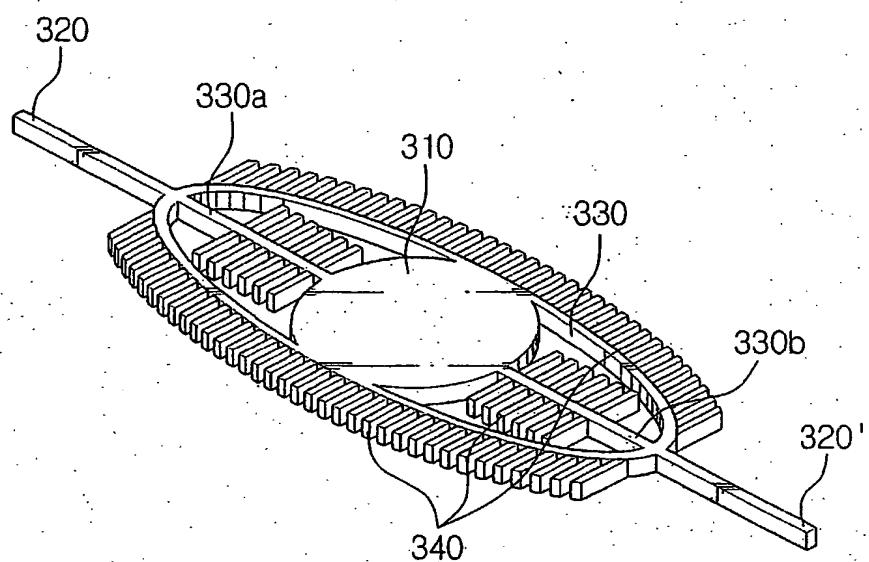


FIG. 8

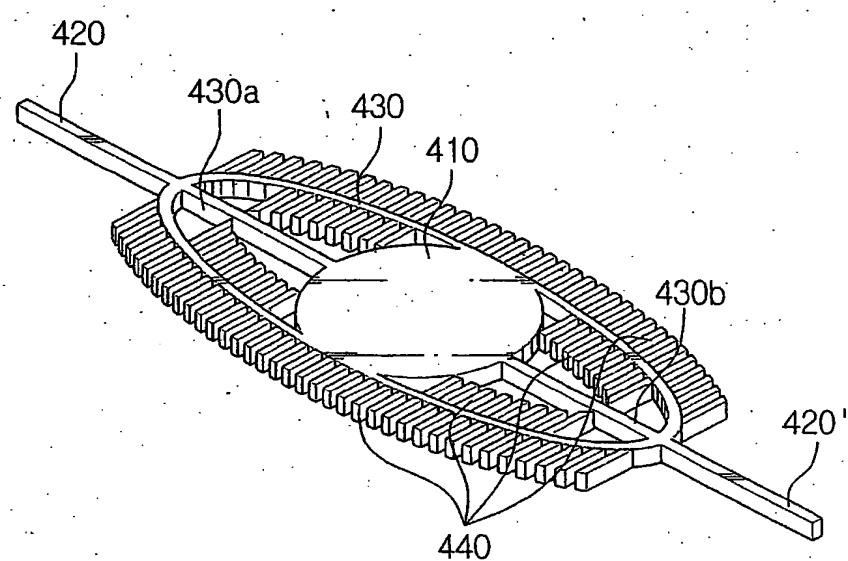


FIG. 9

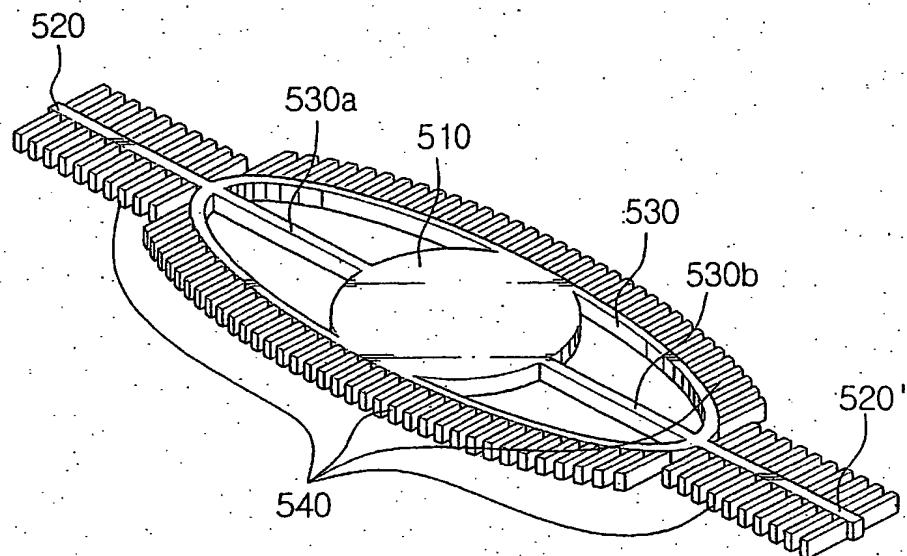


FIG. 10

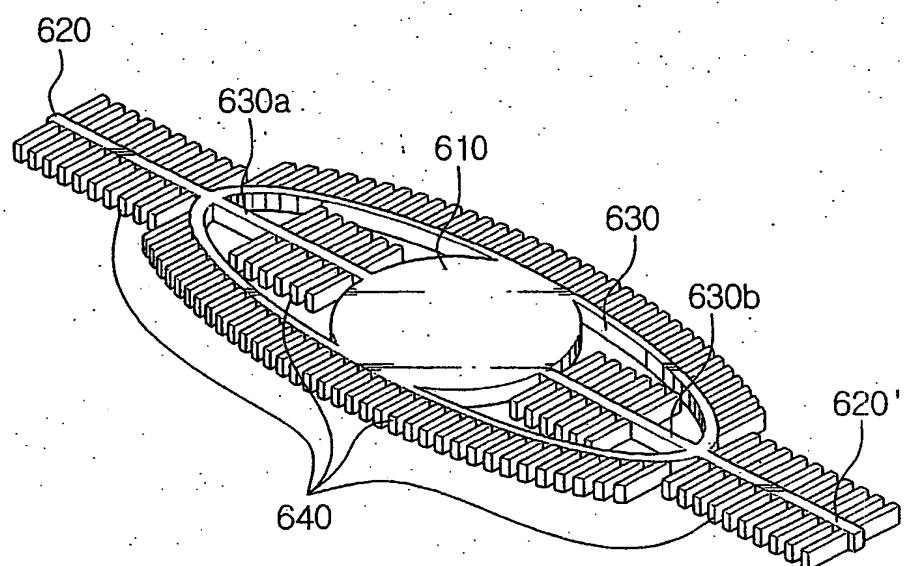


FIG. 11

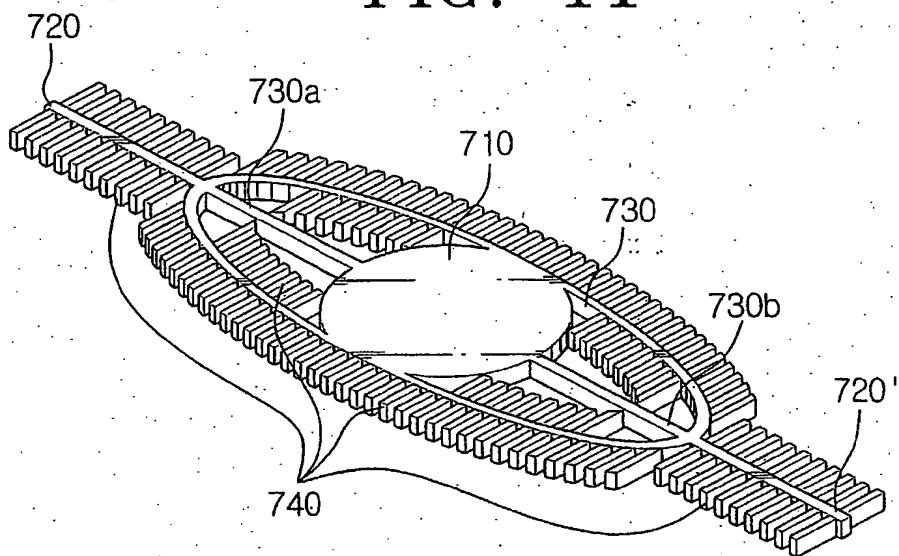


FIG. 12A

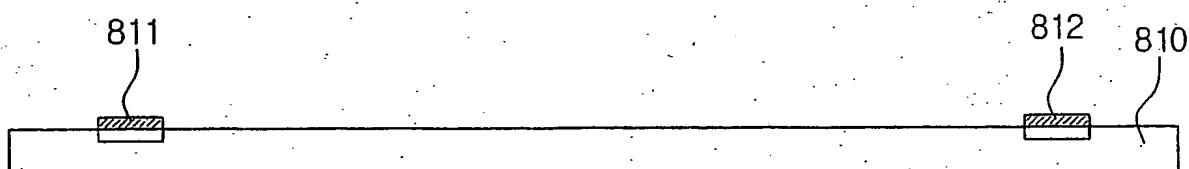


FIG. 12B

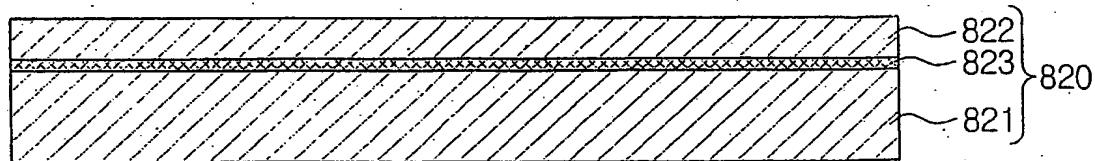


FIG. 12C

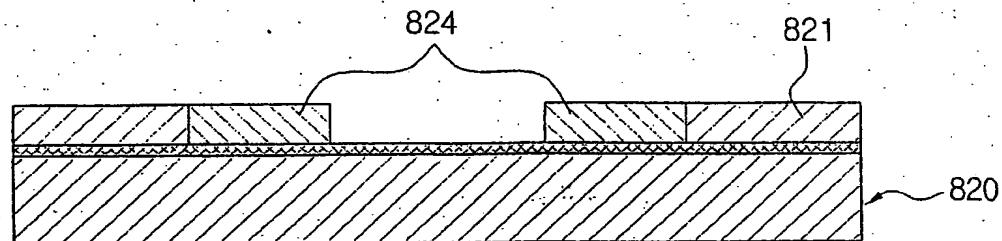


FIG. 12D

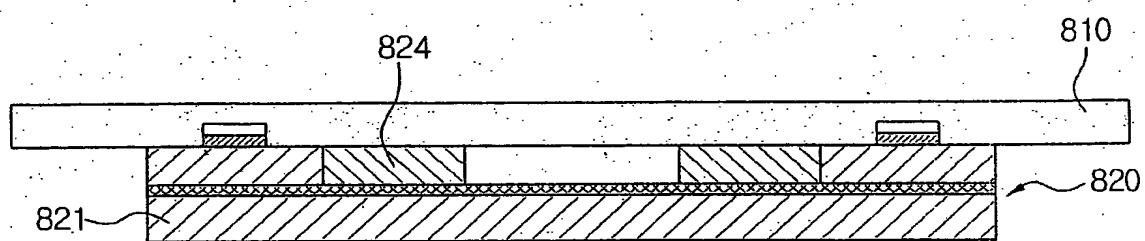


FIG. 12E

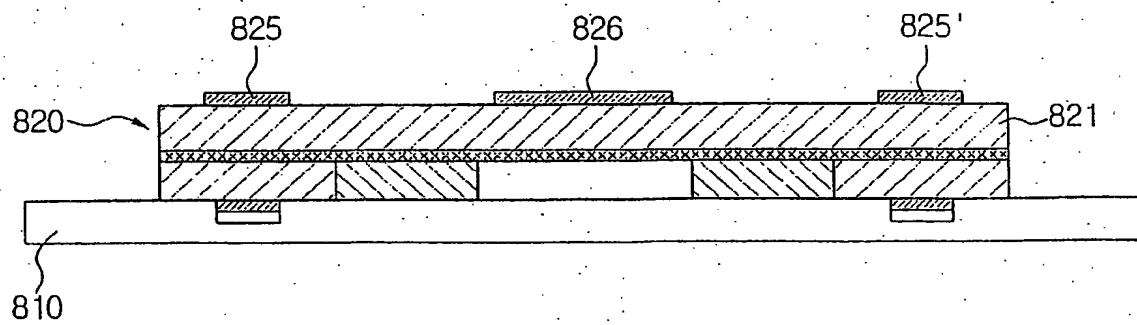


FIG. 12F

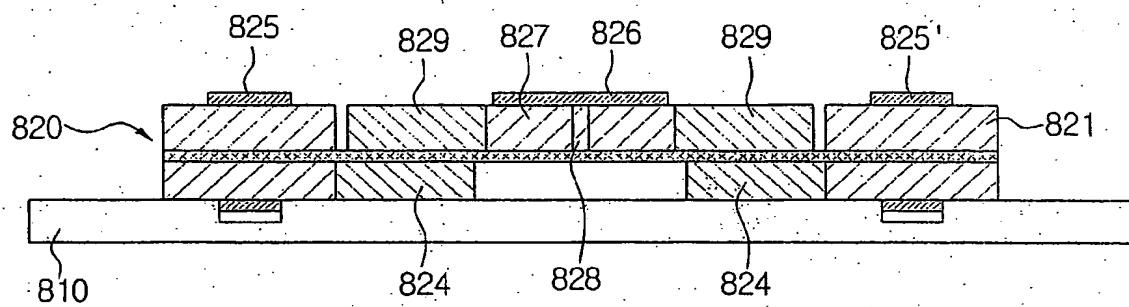


FIG. 13A

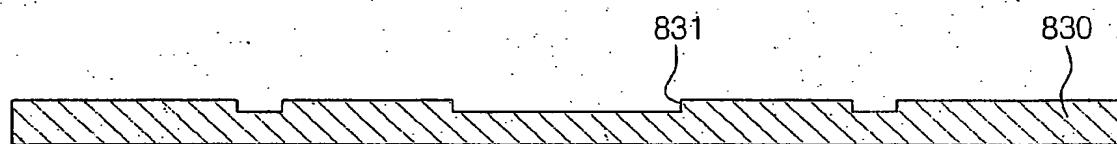


FIG. 13B

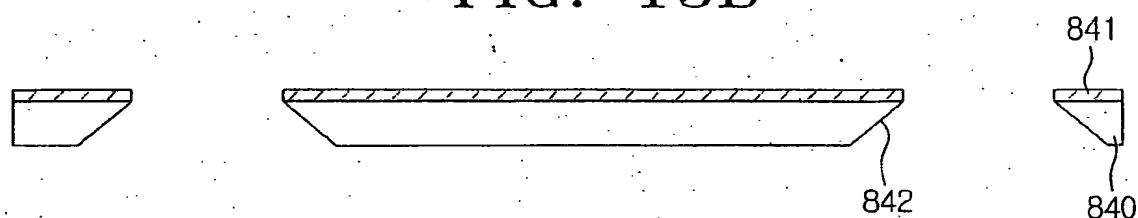


FIG. 13C

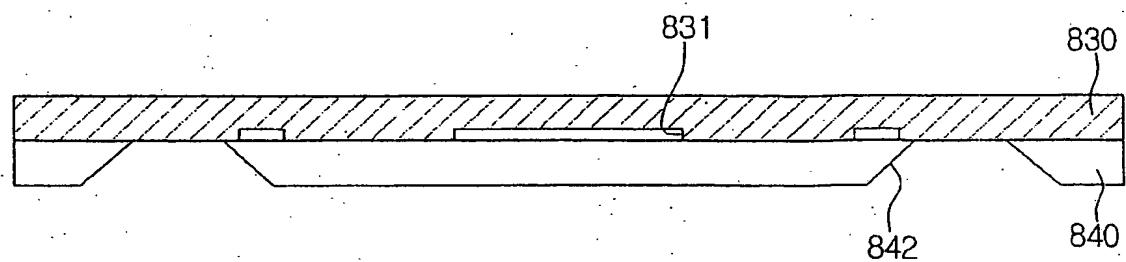


FIG. 13D

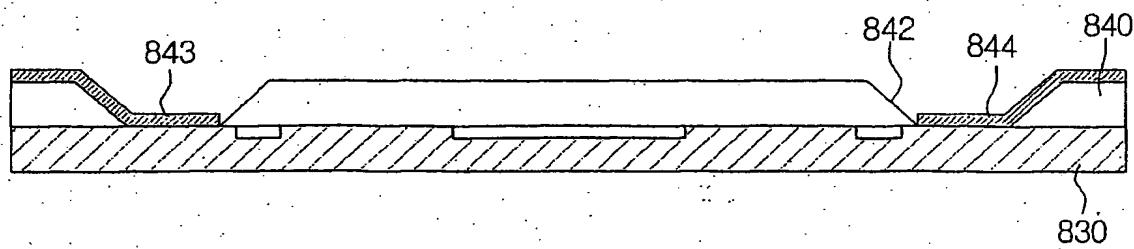


FIG. 13E

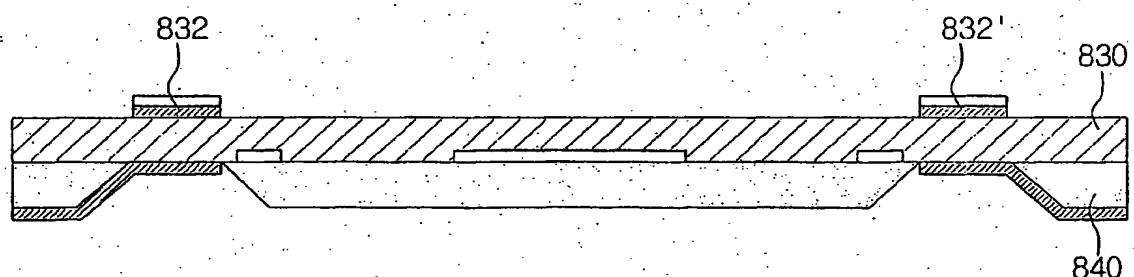


FIG. 13F

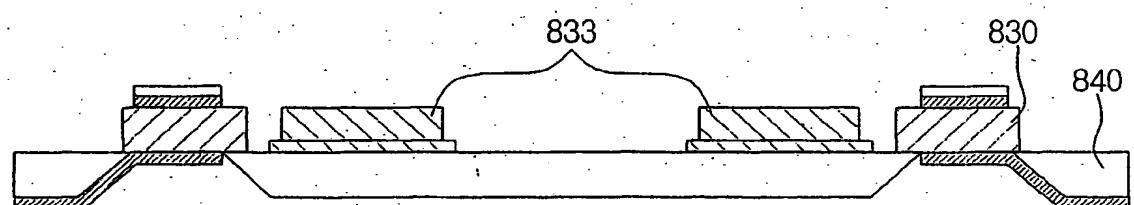
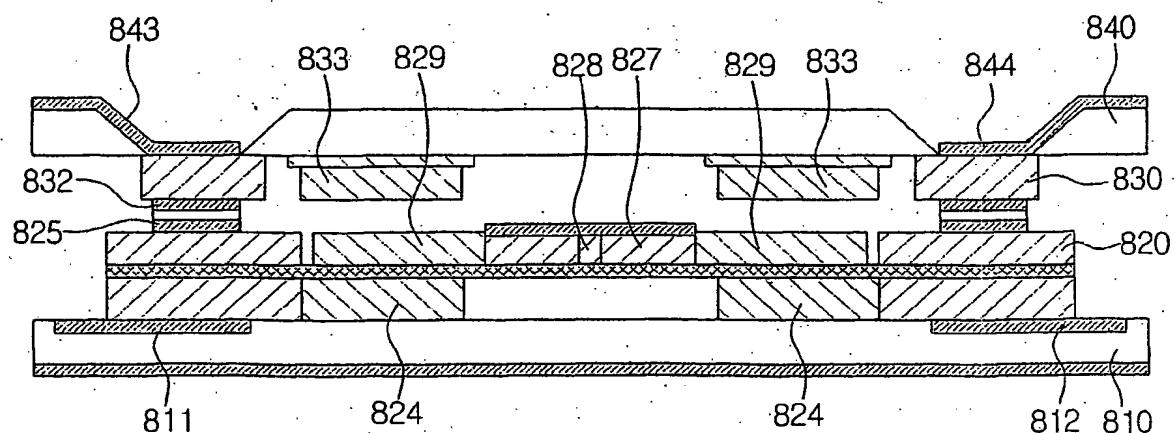


FIG. 14





European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 04 25 5088

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	KRISHNAMOORTHY U ET AL: "DUAL-MODE MICROMIRRORS FOR OPTICAL PHASED ARRAY APPLICATIONS" TRANSDUCERS '01 EUROSENSORS XV. 11TH INTERNATIONAL CONFERENCE ON SOLID-STATE SENSORS AND ACTUATORS. DIGEST OF TECHNICAL PAPERS. MUNICH, JUNE 10 - 14, 2001, INTERNATIONAL CONFERENCE ON SOLID-STATE SENSORS AND ACTUATORS. DIGEST OF TECHNICAL PAPERS, BER, vol. VOL. 2, 10 June 2001 (2001-06-10), pages 1294-1297, XP001154517 ISBN: 3-540-42150-5 * figures 1,2 *	1,2,5,6, 8,9	G02B26/08 G02B26/10
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 197 (P-1523), 16 April 1993 (1993-04-16) -& JP 04 343318 A (FUJI ELECTRIC CO LTD), 30 November 1992 (1992-11-30) * abstract; figure 1 *	1,2,5,6, 8,9	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	US 2003/019832 A1 (LAU KAM-YIN ET AL) 30 January 2003 (2003-01-30) * figure 3 *	1-22	G02B
The present search report has been drawn up for all claims			
3	Place of search Munich	Date of completion of the search 24 January 2005	Examiner Daffner, M
<b>CATEGORY OF CITED DOCUMENTS</b> <p>X : particularly relevant if taken alone      Y : particularly relevant if combined with another document of the same category      A : technological background      O : non-written disclosure      P : intermediate document</p> <p>T : theory or principle underlying the invention      E : earlier patent document, but published on, or after the filing date      D : document cited in the application      L : document cited for other reasons      &amp; : member of the same patent family, corresponding document</p>			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 25 5088

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
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24-01-2005

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